IV. *An Account of some recent Researches near Cairo, undertaken with the view of throwing light upon the Geological History of the Alluvial Land of Egypt.—Instituted by* LEONARD HORNER, *Esq., F.R.SS. L. & E., F.G.S.*

PART I.

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INTRODUCTION.

THE progress of geology has demonstrated, that the portion of the crust of the globe which is accessible to us, has been formed by a series of successive operations, and that each member of the series of great changes must have required a period of vast duration for its development. We learn from the astronomer that the mean distance from our earth to the sun is ninety-five millions of miles, and that the distance which separates us from the 61st star of the Swan is 412,000 times ninety-five millions. Although he thus describes an extent of distance of which it is scarcely possible for us to form a just conception, still he expresses himself in definite terms. Not so the geologist: while the astronomer with his telescope penetrates into the remotest regions of Space, and in the known velocity of light has a scale by which he can estimate the vast distance, the geologist looks into an unfathomable abyss of Time; for no power of sounding its depth has yet been discovered. If he attempts to assign a definite term, in time, for the period of the formation of any particular series of strata, even among those that belong to the most recent of the tertiary deposits, he has hitherto sought in vain for any reliable scale of measurement; and he speaks of thousands, or millions, or myriads of years or ages, just as imagination leads him to give a form to his ideas of vast immeasurable antiquity.

It is scarcely within the range of possibility that the absolute age of the earth's crust, reckoned in years backward from some historical epoch, will ever be disco-

vered, because its formation has been progressive, and the several stages of its growth must each have been so modified by a variety of causes, irregular in their extent, duration, and recurrence, that there would exist no uniformity in the rate of progression.

Although it be thus highly improbable that we can ever form an approximate estimate in years of the age even of the most modern strata, we are not cut off from all hope of being able to assign an amount in years to the duration of some of the great geological changes which, in past ages, the present surface of the earth has undergone, by causes that are still in operation. It has been estimated that the delta of the Mississippi must have required not less than 100,000 years for its formation, and that the recession of the Falls of Niagara to their present position has been the work of many thousand years*. But even here we have probability only to rest upon, strong though it be; may we not hope to arrive at the knowledge of some instances when our estimates may possess some degree of precision, where we may find a link connecting historical and geological time†?

If in a country in which a certain alteration in the land has occurred, we know that such alteration has taken place in part within historical time, and if the entire change under consideration presents throughout a tolerable uniformity of character, shall we not be justified in holding the portion that has taken place within the historical period to afford a measure of the time occupied in the production of the antecedent part of the same change? If a region exists where such a blending, as it were, of geological and historical time occurs, we may then be able to estimate in definite terms, the time that has elapsed since the change in the form and structure of the land under examination first began.

Of the various agencies which modify the earth's surface, rivers are the most constant, the most uniform in their operation within given periods, and the most appreciable in their effects. The materials which they transport from the higher parts of their course are frequently spread over an extensive surface in the lower lands near their mouths, and encroach upon the sea, leaving far inland towns that at one time stood on the shore, But when the foundations of such towns are on detrital travelled materials, they show that similar geological changes had been in progress before the first buildings in these towns were erected. If the date be known when such towns were last frequented as sea-ports, we can judge of the extent of geological change brought about between that period and the present time. But as the more recently transported materials, those which have accumulated during the historical period,

* Sir Charles Lyell, Second Visit to the United States, vol. ii. p. 250, and Travels in North America, vol. i. p. 34.

† Strictly speaking, the present day is "geological time;" for not an hour passes without the crust of the earth, externally and internally, undergoing a change. Meteoric forces are ever acting on the rocks, rivers are transporting to distant parts the loosened particles, and springs and volcanic forces are bringing up from the interior materials that are spread over the outer surface of the earth.

may have been brought down at irregular intervals, and by unequal increments, they afford no data by which we can estimate the rate of increase of the detritus brought down by the same river, previously to the foundation of the sea-port town; nor can we discover whether the formation of the land, composed of travelled materials, on which the town was built, and which stretches far inland from it, was the operation of a brief period of time or of one continued through a long series of ages.

Egypt affords the earliest authentic evidence of the existence of the human race, recorded in works of art; in its monuments we find the dawn of the historical period and of civilization; and that land alone, of all parts of the world as yet known to us, offers an instance of a great geological change that has been in progress throughout the whole of the historical period, down to the present day; and which, we have very reasonable grounds for believing, had been going on with the same uniformity for ages prior to that period when our reckoning of historical time begins. I refer to the annual inundation of the Nile, and the sediment that falls from its waters on the surface of the land it overflows.

The question of the raising of the valley of Upper Egypt and the formation of the Delta by the deposit from the Nile, has been a subject of controversy from the days of Herodotus to our own time: there is scarcely a writer on Egypt who does not allude to it. Herodotus, who visited Egypt about 455 years before our era, says * that "the soil of Egypt is a black earth, cracked and friable, as if it had been formed by the mud brought down by the Nile from Ethiopia, and which has been accumulated by its overflowings. The greater part of the land is a present from the Nile, as the priests informed me, and it is the conclusion to which I have myself arrived. It seemed to me, in truth, that the whole extent of country lying between the mountains above Memphis was formerly an arm of the sea." Thus far his conclusions are in the main correct; but he goes farther, conceiving that Lower Egypt was wholly formed within historical time; for he says, "in proportion as the land extended from Upper Egypt by the deposits of the Nile, a part of the inhabitants migrated into Lower Egypt." This latter theory of Herodotus, which an examination of the geological features of the country has shown to be erroneous, was even recently adopted by the acute and learned Niebuhr, as we learn from the lectures he delivered at Bonn, a very short time before his death †.

The theory of Herodotus, supported by Aristotle, Diodorus Siculus, Seneca, Strabo, Pliny and Plutarch, was combated in a learned disquisition, in the Memoirs of the Academy of Inscriptions and Belles Lettres, by Freret, bearing the date of 1742 ‡, and this memoir was replied to fifty years afterwards by the eminent geologist Dolomieu §. The latter author observes, that the question of the effects of the inundations of the Nile on the formation of the Delta had been treated of by the

* Book ii. 10 and 15. † Alte Geschichte, vol. i. pp. 50. 56. 79. ‡ vol. xvi. p. 333.

§ Sur la Constitution Physique de l'Egypte, par M. Deodat de Dolomieu, Journal de Physique, 1793, tome xi. ii. p. 41.

learned, by an examination of, and quotations from, ancient writers; whereas the problem to be solved was more one of physical geography, and belonged more to the geologist than to the man of letters. Admitting the theory of HERODOTUS as to the mode of formation of the Delta, he combats that part of it in which he refers the operation to historical time.

That there has been an annual inundation of the Nile, of greater or less amount, from the earliest period to which history or tradition reaches, does not admit of a doubt; and it is equally certain that the river so flooded was loaded with solid materials, for the fertilizing effect of a sediment left upon the ground is recorded equally with the fact of an annual inundation*. Unless therefore this same addition was wholly washed away again from the surface between the fall of the water of one year and the rise of the next, there must have been an accumulation from year to year. That the fertilizing effect of the inundation is exhausted, or nearly so, is true; but in a country where there are no streams tributary to the main river, where rain is almost unknown in the greater portion of it, that is in Upper Egypt, and with an inclination so slight as that of the land over which the inundation spreads, the solid insoluble matter must in great part remain where it is deposited. That the fertilizing effect of the inundation is increased in proportion to the depth of the water, is shown by the unequivocal proof that the taxes, from time immemorial, have been levied upon the land according to the height to which the river rises†. It was to regulate this impost that the Nilometer on the island of Elephantine near the First Cataract was erected in ancient times, and that a similar instrument was set up in the island of Rhoda, near Cairo, a thousand years ago.

To investigate the formation of the alluvial land in the valley of the Nile in Upper and Lower Egypt is therefore an object of the highest interest to the geologist and the historian. Nowhere else on the face of the earth can we hope to find such a link connecting the earliest historical with the latest geological time; for in Egypt we have accurate records of the earliest periods of the human race, in which any trace of civilization has been discovered, combined with records, of scarcely less accuracy, of geological changes contemporaneous with history, and these last having such a degree of uniformity as to warrant us in carrying back the dates of changes of a like nature beyond that of the earliest historical documents.

Having been long impressed with a conviction that this geological problem could only be solved by having shafts and borings made in the alluvial deposits to the greatest practicable depth, and concurring in the opinion, long ago expressed by CUVIER, that it was a matter of regret that the depth of these deposits between the surface and

* How much the fertilizing effect of the inundation belongs to the solid matter held in suspension and deposited on the land, and how much belongs to the matter held in solution in the water, is a question that, so far as I know, has not been solved.

† Beyond a certain height, it is disadvantageous, as the water has not drained off sufficiently to leave the land in a proper state at the right sowing time of the following year.

the rock on which they may rest had not been ascertained, I determined to make an effort to have the experiment made, even to the limited extent within my means, as the results thus obtained might lead the way to other researches on a greater scale.

The ground upon which I hoped to be able to form a chronometric scale by which the total depth of sediment reached might be measured, was the same as that on which the French engineers in 1800 had proceeded, viz. the accumulation of Nile sediment around monuments of a known age. Certain works of art of a very early age exist near the Nile, the approximate dates of whose erection have been established upon reliable evidence; and we know also that the sediment has accumulated to a considerable height above their base. If that depth of sediment be divided by the number of centuries that have elapsed since the date of the erection of the monument, we obtain a scale of the secular increase of which the base of the monument is the zero, assuming, as we are entitled to do, that the average increase from century to century has been uniform within an area of some extent. If the excavation be continued below the base stone, and the sediment passed through exhibits similar characters as to composition with that above the base line of the monument, it would be fair to apply the same graduation below the zero-point of the scale as above it; and, if we reached so far, we should be able to estimate the time that has elapsed since the first layer of sediment was deposited on the rock forming the channel over which the water spread when it first flowed northward from its source in the interior of Africa; subject, however, to correction for causes that might make a difference in the rate of increase between earlier and later periods; an investigation of which causes forms a necessary, but a very difficult part of such an inquiry.

I submitted my project to the President and Council of the Royal Society, stating, that it appeared to me to be a scientific inquiry of sufficient importance to justify my asking for a grant from the Donation Fund under their control, for the purpose of defraying the expense of the proposed excavations. My proposal was favourably received, and the Council were pleased to place a liberal grant of money at my disposal.

I have thought it advisable, before entering upon the narrative of the researches carried on towards the accomplishment of the object of this inquiry, to give a brief sketch of the physical geography of Egypt and of its geological structure; and a somewhat more detailed account of the annual inundations of the Nile and of the sediment it deposits.

Physical Geography and Geological Structure of Egypt *.

Egypt is separated from Nubia by a low hilly region, fifty miles in breadth from north to south, which is a part of a range extending from the Red Sea in an east and

* The principal authorities are,—Russegger, Reisen in Europa, Asien und Africa, Stuttgart, 1843; Brocchi, Giornale delle Osservazioni fatte ne' Viaggi in Egitto, &c., Bassano, 1841; Newbold, Quarterly Journal of the Geological Society, Nov. 1848; and Talabot, Mémoire de la Société d'Etudes de l'Isthme de Suez, 1846–47,—the latter not published.

west direction until it gradually sinks in the desert of Libya. This part of the range nowhere rises to a greater height than about 214 feet above the bed of the Nile, and 546 feet above the Mediterranean. Granite is the predominant rock, of different varieties, sometimes passing into gneiss, sometimes having an admixture of hornblende, when it gets the name of syenite, from its occurrence near the ancient town of Syene.

The granites and other unstratified rocks are associated in the district near Assouan, or the First Cataract, with two sedimentary rocks, both sandstones, and very similar in mineral structure, but very different in point of age; for the one belongs to the lower members of the cretaceous period, and the other covers in several places, farther north, a tertiary nummulite limestone.

Through a labyrinth of these granites and sandstones, extending from the island of Philæ to the neighbourhood of Assouan, the Nile enters Egypt in a succession of rapids, having a descent of about 85 feet in a distance of about five miles and a half from Philæ to Assouan, forming what is called the First Cataract. There is no waterfall, as commonly understood by the term cataract, for RUSSEGGER and his companions were dragged up in a boat the whole distance in two hours, during the time of low water, that is, towards the end of January.

The valley of Upper Egypt is flanked by two parallel ranges of hills, the Arabian on the east, the Libyan on the west. At Assouan, the southern extremity of the valley, they each approach close to the Nile, the bed of which is strewed with rocky islands, the most northernly being the celebrated Elephantine. Both ranges are divided by rents of various magnitudes, forming valleys, some of them running north and south, others crossing the ranges from east to west. One of the great north and south valleys gave a passage to the waters of the Nile, in a somewhat tortuous course; the appearance of the boundaries on either side, and the very gentle fall of the land, from south to north, excluding all idea that the valley has been excavated by the action of running water. The Nile valley varies considerably in breadth, its widest part between Minieh* and Benisuef being about eighteen miles, frequently contracting to two miles; and at Gebel Silsilis, about forty-five miles below Assouan, the hills approach so close to each other, that the river, for three-quarters of a mile, runs through a pass about 1200 feet wide†, and there is scarcely a yard of alluvial deposit on either bank for a considerable distance. At the apex of the Delta the valley is six and a half miles wide‡.

The Libyan range falls with a slope towards the valley, the rocks of which it is composed appearing to extend under the valley, forming a solid basin covered with sand and detritus that had accumulated before the alluvial matter brought down by the Nile began to be deposited over it.

The Arabian hills, except where broken by transverse valleys, present cliffs towards

* In the spelling of the proper names, I follow LEPSIUS in his Briefe aus Ægypten, 1852.

† According to the atlas that accompanies the Description de l'Egypte, 200 Toises.

‡ BONOMI, Trans. of Roy. Soc. ot Lit., 2nd Series, ii. 297.

the river, nearly throughout their whole length. In the neighbourhood of Assouan the hills are little more than 200 feet above the Nile, but they go on increasing in height to the parallel of Thebes, where they attain an elevation of 1065 feet above the Nile; and from that point, northwards, they have a gradual fall, but rise again in some parts of their northern extremity to nearly 1000 feet.

The Libyan and Arabian ranges are nearly identical in mineral composition. The lowest sedimentary rock exposed to day, that which comes in contact with the igneous rocks above Assouan, is the lower sandstone above described. It constitutes the chief composition of the hills on both sides of the valley as far north as the neighbourhood of Esneh, about eighty-five miles below Assouan. Here it is covered by a limestone which both Russegger and Newbold identify with the chalk of Europe, the former considering it to belong to the period of the upper chalk. It occupies both sides of the valley as far as Siut, a distance of nearly 130 miles, in a direct line.

At Siut the chalk is covered by nummulite limestone, a part of that vast tertiary formation which extends through Southern Europe, Asia and Northern Africa. The hills on both sides of the valley from Siut to Cairo, a distance of more than 200 miles, are composed of it, and it extends from the Nile to the Red Sea, and from the left bank of the river into the Libyan desert.

In the latitude of Cairo the Arabian and Libyan ranges of hills no longer run parallel; the former terminating in a line from W.N.W. to E.S.E., between Cairo and Suez, so that near Cairo the hills on the right bank of the Nile appear to turn abruptly, nearly at right angles to the course they have held from Assouan northwards. Near Cairo the group of Gebel Mokattam rises to the height of 448 feet above the Mediterranean. The hills composing the northern part of the Libyan range, from the latitude of Cairo take a N.W. direction, being a continuation of the hills that extend from the Red Sea. They in no part rise to a greater elevation than about 320 feet above the Mediterranean.

North and east of the Mokattam, the different members of the tertiary nummulite limestone formation are covered by a sandstone, identical in character with the upper sandstone near Assouan. No fossils have been found in it hitherto, but its overlying the nummulite limestone clearly determines it to be at least a tertiary deposit. This sandstone is the prevailing rock throughout the Isthmus of Suez, wherever it rises above the desert sand or other alluvial covering.

The engineers who accompanied the French army in Egypt in 1799, having made a survey of the Isthmus of Suez, came to the conclusion that the level of the Red Sea was 9 metres (29 feet 5 inches) above that of the Mediterranean, and their high reputation gave currency in the scientific world to this result for many years. Circumstances, however, having in more recent times thrown doubts on the accuracy of the survey, which had been made in a very short time, and under almost every disadvantage, a private association of French, English and Austrian civil engineers

was formed in 1846, under the patronage of the Viceroy of Egypt, MEHEMET ALI, for the express purpose of making a careful survey of the isthmus, in order to determine the question of the level of the two seas. The association consisted of Messieurs TALABOT and BOURDALOUE on the part of the French, Mr. ROBERT STEPHENSON on the part of the English, M. NEGRETTI on the part of the Austrians, and M. LINANT DE BELLEFONDS (Linant Bey) on the part of the Pacha. Mr. STEPHENSON undertook to observe the levels of the tides at Suez, M. NEGRETTI those at Tineh on the Mediterranean, near the ancient Pelusium, and the survey of the land was undertaken by M. TALABOT and M. BOURDALOUE with several assistants. A report of their operations, accompanied by maps on a large scale, and detailed tables, was printed at Nismes in 1847, under the title of "Société d'Etudes de l'Isthme de Suez, Travaux de la Brigade Française, Rapport de l'Ingénieur," but has not been published*. The results obtained were as follows:—

That the low-water mark of ordinary tides in the two seas, at Suez and at Tineh, is very nearly on the same level, the difference being, that at Suez it is three centimetres lower, that is, rather more than 1 inch;

That the mean rise of ordinary tides in the Red Sea is somewhat higher than in the Mediterranean, but that the maximum difference is not more than 80 centimetres, or $31\frac{1}{2}$ inches;

That the rise of the equinoctial spring tides at Suez over the low-water mark in the Mediterranean at Tineh at the same period is 2·38 metres, or 7 feet 9 inches; and

That the deepest low-water mark at the same period at Suez is 0·45 metre, or 17·7 inches under the deepest low-water mark at Tineh.

The highest point of the isthmus between Pelusium and Suez is 12·74 metres, or 41 feet above the Mediterranean, the distance between the two places being $12\frac{5}{8}$ myriametres, or about 78 English miles.

The north-westernly prolongation of the Libyan range of hills, which form the western boundary of Upper Egypt, is composed of the same nummulite limestone, covered by the upper sandstone. The sandy desert at the foot of the range, like that on the eastern or Arabian side, contains pebbles of agate and flint, and masses of fossil wood, stems of which have been found 40 feet in length changed into hornstone. Parallel to the direction of the Libyan hills, and on their eastern side, are two depressions of great extent, one of which there is every reason to consider as a former channel of the Nile, and goes by the name of the Valley of the Waterless River; the other is the Valley of the Natron Lakes.

Lower Egypt, geologically considered, is formed of the low and almost level land included between the Mediterranean and the hilly regions which form what may be termed the natural boundary of Upper Egypt. The central portion formed by the divergence of the Nile about sixteen miles below Cairo, into two branches that fall into the sea at Rosetta and Damietta, constitutes the present Delta. The distance

* I have had it in my possession through the kindness of Mr. ROBERT STEPHENSON.

from Cairo to the sea in a direct line is 106 miles, and from Rosetta to Damietta, or the base of the triangle, in a direct line, eighty-two miles, but following the sinuosities of the coast about ninety miles. In earlier times, when the Nile flowed in the Valley of the Waterless River, and when a branch entered the sea at Pelusium, near the modern Tineh, the base of the Delta must have been about 170 miles, but the low land extends beyond each of these limits*.

Lower Egypt is thus a vast plain of alluvial land, with scarcely any natural elevations except the sand-hills near the coast; it is furrowed in every direction by a multitude of natural and artificial canals. The central part is composed of the mud deposited by the Nile, and of sand brought down by the inundations, or blown from the desert on either side; and all around the plain the boundary of Lower Egypt is composed of quartzose sands, that are generally white on the east, and reddish-white on the west, and the ground which these sands cover is at a higher level than that of the Nile at its highest inundations.

Two great shallow lakes, Burlos and Menzaleh, occupy the greater part of the base of the modern Delta, besides smaller lakes, lagoons and swamps, behind the sand-hills that line the coast. These sand-hills rest upon a reef which forms a powerful dam against the encroachments of the sea, and which RUSSEGGER describes as being in a continual state of formation and waste; as being a calcareous stone of a dirty grey colour, composed of sand mixed with worn fragments of ordinary marine testacea, mingled with microscopic shells, many of the latter being of freshwater and land origin, brought down by the Nile, thrown up again by the sea and mingled with marine shells. In structure the stone is not usually very coherent, but in some places it is hard enough to be used for building, and in ancient times numerous catacombs were excavated in it, some of which are the so-called baths of Cleopatra.

At the island of Philæ, about five miles above Assouan, may properly be placed the first entrance of the Nile into Egypt. The mighty stream has here a breadth of nearly one mile†, but soon after it is divided into several branches, by the rocks that rise up in its bed to form the most northern of the rapids, the First Cataract, of which many occur in the higher parts of its course. The breadth of the river is here contracted to about a third of a mile. From the junction of the Atbara in latitude 17·38 N. until it reaches the sea in latitude 31·25, or nearly fourteen degrees of latitude, the Nile does not receive a single tributary, with the exception of torrents after heavy rains in the lower parts of its course in Egypt, from the hills on either side. Assouan, according to the barometrical measurements of RUSSEGGER, is 300 feet

* "Although it has been usual to commence Egypt at Tineh (Pelusium), some geographers have restored it to the ancient point El Arish (Rhinocorura), the southern boundary of Syria. Between this and Tineh are the moving sands called by the Hebrews Shúr, and by the Arabs Al Jofár, bordered by the Serbonian Pool. From this notable landmark the shores of Egypt extend to Rasal Kanâis, about 115 leagues to the westward. The central portion is the Delta."—The Mediterranean, by Admiral SMYTH, pp. 83, 84.

† 1500 metres=1640 yards, by the Atlas of the Description de l'Egypte.

above Cairo, and the distance between the two places by the Nile being 556 miles, the average fall of the river is little more than half a foot in a mile, viz. 0·54 ft.; and Assouan being 365 feet above the Mediterranean, and 696 miles distant from it, the average fall of the Nile from the foot of the First Cataract to the sea is 0·524 ft. in a mile*. RUSSEGGER does not give the place in Cairo from which he measured the above 300 feet, but by the careful measurements of the French Brigade in 1847, before referred to, M. TALABOT states the lowest water of the Nile in the Nilometer of Rhoda near Cairo in that year to have been 14·08 metres, or 46 feet 2 inches above low-water mark of the Mediterranean at Tineh; and the distance to the mouth of the Damietta branch, following the course of the river, being 149 miles, the average fall is thus only $3\frac{3}{4}$ inches in a mile.

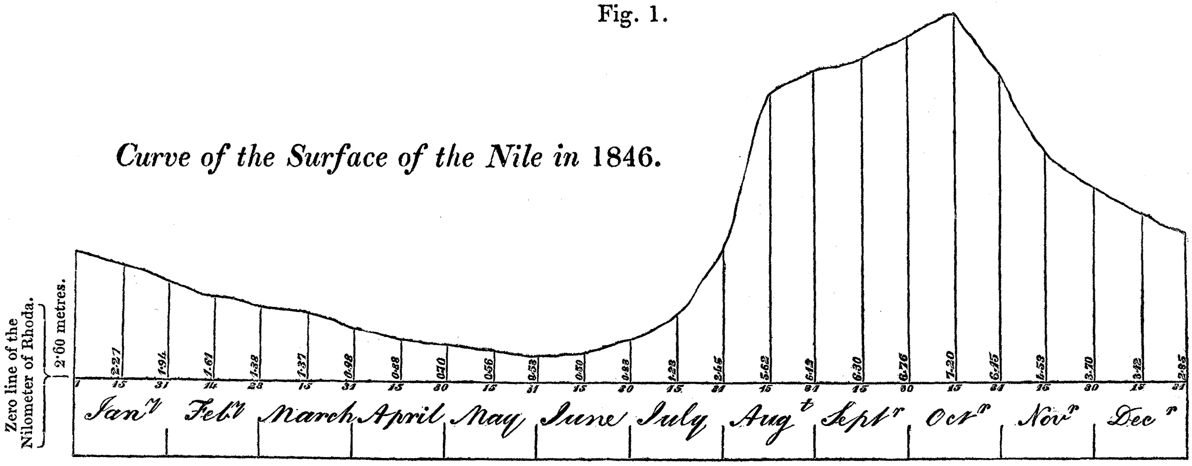
The Inundations of the Nile.

The commencement of the rise of the Nile, immediately below Assouan, is about the summer solstice. The first rise at Cairo, indicated by an increasing motion in the stream, is usually in the first week of July. The rise is scarcely perceptible for six or eight days, and it then becomes more rapid. About the middle of August it has obtained two-thirds of the height between the lowest ebb and highest rise. At this period the water enters the great side branch on the left bank, the Bahr el Jusef, Joseph's Canal, called also the Magrour, and now is the time when the artificial branches or canals are opened, the commencement of the inundation over the parched plains. The rise attains its maximum between the 20th and 30th of September, and this state of the inundation is called the *Salibe*. The water remains pretty stationary for fourteen days; it then begins to fall, at first at a more rapid rate than that with which it rose, but after it has fallen one-half, the decrease is very gradual. About the 10th of November it has usually fallen one-half, and it goes sinking slowly until somewhat beyond the following May. The rise of the river continues therefore about ninety days (from 1st of July to 28th of Sept.), but it continues falling about 230 days (12th of October to end of May). The changes of level are well illustrated by the annexed diagram, given to M. TALABOT in 1847 by Mougel Bey, the engineer for the Barrage of the Nile at the apex of the Delta.

* RUSSEGGER, Reisen, ii. 271. The fall of the Thames from Chertsey to Teddington Lock, a distance of $13\frac{1}{2}$ miles, is nearly $17\frac{1}{2}$ inches in a mile. See RENNIE, Report to the British Association in 1834, p. 487.

"Colonel CAUTLEY, the projector of the Ganges Canal (recently constructed), decided after careful thought and due regard to the experience gained on canals previously opened, that a fall of fifteen inches in every mile of length would best secure the desired ends."—Short Account of the Ganges Canal, p. 7.

Fig. 1.



Curve of the Surface of the Nile in 1846.

0·50 metre=18,685 English inches. 7·20 metres=23½ feet.

From the increased fertility of the land by the overflowing of their river, the earliest inhabitants of Egypt must have been led to watch the rise and fall of the water with anxious care. At an early period in the history of the country they contrived an instrument to measure its diurnal changes, a Nilometer, which was erected on the island of Elephantine near Assouan. That instrument is now only an object of interest to the antiquarian, as a ruin is all that is left of it; but it was in a state of considerable preservation a little more than fifty years ago when visited by the French engineers*. I describe it now, as it then existed, because special reference will be made hereafter to this ancient standard of the Nile's annual increase. It is near the south end of the island, and is described by Strabo from personal observation, he having twice visited the spot.

The French engineers have given the following description of it as they found it. It was in a building constructed of regular horizontal layers of sandstone, having two flights of steps, at right angles to each other. One of the walls of the staircase was marked with a vertical groove, crossed by horizontal lines, at regular distances, each of these divisions being a cubit. Three of these divisions were marked with the Greek numerical letters, the highest being ΚΔ, or 24; the second ΚΓ, or 23; the fifth Κ, or 20. The engineers assumed that at the time this Nilometer was constructed, the number 24 marked the greatest rise of the Nile then known†. M. Girard and his companions made an exact measurement of the cubits from 24 to 18, and the result gave 527 millimetres for each cubit, =20·75 English inches. Sir Gardner Wilkinson, from personal observation and examination of the different

* Among the scientific men who accompanied the French army in 1799, we find the following celebrated names:—Berthollet, Monge, Fourier, Malus, Girard, and M. Cordier the geologist, still living. M. Girard occupied the rank of Ingénieur en Chef des Ponts et Chaussées. Dolomieu also went, but did not remain.

† Girard, Observations sur la Vallée d'Egypte, et sur l'exhaussement seculaire du Sol qui la recouvre: Mémoires de l'Acad. Roy. de l'Institut; 1817, tom. ii. p. 261, and Description de l'Egypte Antique, sur le Nilomètre de l'Ile Elephantine.

Egyptian cubits, informs us, that every cubit is divisible into fourteen parts, each of two digits, and the length of the cubit being 20·625 inches, we have 0·736 inch for each digit. It will thus be seen that the measurements of Sir G. WILKINSON and those of the French engineers very nearly agree, the difference being only between 20·75 and 20·625.

Upon the island of Rhoda near Cairo a Nilometer was erected more than a thousand years ago, and is the only measure of the rise and fall of the Nile referred to in the present day. It is known by the name of the MEKYAS (instrument of measure). For a reason that will afterwards appear, I give the description of it by the French engineers in 1800. They describe it as an octagonal pillar, having a scale divided into 16 cubits, and each cubit into 24 digits. Each cubit of this scale they found to be equal to 541 millimetres, or 21·3 English inches*.

Between the first entrance of the Nile into Egypt and its mouth, the mass of water must be vastly diminished from the following causes: it receives no tributary; spread over so wide a surface under a burning sun and a cloudless sky, the evaporation must be very great; the water is drawn off from the main channel by numberless canals, and there is a further absorption by infiltration through the soil, for several miles inland, on the left bank in Upper Egypt, and on both sides in Lower Egypt. Thus, while the rise of the river at the island of Rhoda on an average of years is 24 feet, near Ramanyeh about sixty-five miles in a direct line north of the apex of the Delta, the difference between highest and lowest water is about 13 feet, and at Rosetta and Damietta not more than 42 inches †.

From observations made in 1799 at Siut, about midway between Assouan and Cairo, the French engineers estimated the volume of water in the Nile to be as follows:—that every second of time a mass of water passes a given line across the river equal to 678 cubic metres at low Nile, and 10,247 cubic metres at high Nile‡. Linant Bey states that the volumes near Cairo are 414 cubic metres at low Nile, and 9440 at high Nile. M. TALABOT makes on this subject the following observations:—"En partant des données qui fournit M. GIRARD dans son Mémoire sur la Vallée d'Egypte, j'ai cherché à calculer le produit moyen du Nil; il resulte de ce calcul, que la hauteur moyenne du Nil, d'après les quatre années d'observations certaines qui nous ont été fournies, soit par l'Expedition, soit par M. MOUGEL, étant de 3m·23, correspondrait à un débit moyen de 2860 mètres cubes par seconde, ou d'environ 90,000 millions de mètres cubes par an." But the Rosetta branch, at its mouth, is not more than about 600 metres (656 yards) wide, and at lowest water the depth is only 1·60 metre (5 feet 3 inches); in the Damietta branch the width is about 300 metres (328 yards), and the depth, at the same period, 2·50 metres (8 feet 2½ inches)§.

* Description de l'Egypte, vol. xviii. p. 603.

† LANCRET et CHABROL, Descr. de l'Egypte, Etat Moderne, tome ii. p. 187.

‡ GIRARD, *loc. cit.* 208.

§ GIRARD.

When we consider, therefore, the large amount of earthy matter held suspended in the water, as will presently appear, and how much the volume of water is diminished before the Nile reaches the sea, it is evident that a vast amount of sediment must be annually left upon the land which the inundation overspreads, that a much larger proportion must be deposited in Upper Egypt than in the Delta, and, from the greater surface of the latter, that the depth of the annual accumulation there must be greatly less than in the more contracted part of the valley.

The solid matter conveyed by the Nile, to form its sedimentary deposits.

When the inundations commence the Nile comes down of a reddish colour, loaded with sand and mud. From the small amount of the fall between the cataract at Wadi-Halfa (the second) and that at Assouan (the first), a distance of 214 miles, and the difference of height between the two places being only 157 feet*, thus making the average fall of the river not quite 9 inches in a mile, it is not to be expected that much coarse gravel can be carried forward, and that which arrives at the island of Philæ must be much sifted and comminuted in its passage through the rocks forming the rapid of Assouan. Below that place, the fall of the land goes on diminishing, so that the transporting power of the stream is small. The greater proportion of the heavier detritus thus falls down in the higher parts of Upper Egypt, and from the very gentle slope of the Delta, it might be concluded that only a small amount of the solid matter suspended in the water can reach the mouths of the river. But very fine particles of earthy matter, as is well known, are long in subsiding, and much is carried out to sea†. HERODOTUS notices that during the inundation the sea is rendered turbid, and BRUCE observed the same thing. NEWBOLD states, that he found the sea coloured at a distance of forty miles from the shore.

A modern traveller thus describes the appearance of the water in the Nile opposite to Thebes on the 7th of November:—"Ce sera curieux pour nous de revoir ce Nil lorsque l'eau en sera transparente, au lieu d'être, comme maintenant, de la couleur de café-au-lait très noir;" and he says of it three weeks before at Cairo, "Maintenant que l'eau est à son plus haut niveau, elle est d'une épaisseur inconcevable, presque comme du chocolat, et plus foncée‡."

The sediment is slightly modified in character at various localities, according to the nature of the formation near to which the river flows. Its composition and texture are also subject to variation from its proximity to or distance from the main channel of the stream, where the coarser and heavier siliceous particles are usually

* See a paper by the author in the Edinburgh Philosophical Journal for July 1850.

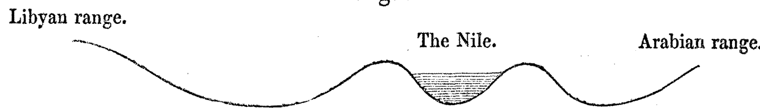
† "The out-pouring of the Nile during the inundation is so powerful that fresh water may be skimmed off the surface of the sea at the distance of two or three miles out in the offing. During the full surcharge, potable water may be baled on the surface of the Mediterranean even out of sight of land."—The Mediterranean, by Admiral SMYTH, p. 84 and 169.

‡ MELLY, Lettres d'Egypte et de Nubie, printed for private circulation, 1852.

found, whereas the finer and more argillaceous and calcareous portions are held in suspension and carried out laterally by the gently overspreading waters.

A transverse section of the valley often presents the following appearance.

Fig. 2.



In the middle we see the Nile, and on both sides of it elevations of the ground like two dams. These run parallel to the river and form its banks. Beyond these, the ground again sinks and forms depressions, which, for the most part, are deeper than the present bed of the river, so that it flows, as it were, on a great dam. The explanation of this is, that the Nile accumulates more alluvium in its immediate neighbourhood, and this chiefly consists, though not always, of gravel and sand, whereas in places more distant, to which the water never reaches except during the inundation, or is conducted by canals, less alluvium is deposited; but as the water remains long there in a tranquil state, it lets fall the more fertilizing mud, and thus the land near the desert is the most productive. But in some places the banks of the river consist of from 23 to 33 feet of pure mud, sometimes divided by layers of sand. In numerous places, beds of mud may be seen rising from the level of low-water to the summit of the bank, and in digging below the lower level, the mud is frequently found to be continued*. Newbold found some banks exhibiting what he considered to be stratified annual layers, varying from an inch to a few lines in thickness, in the same situation, the upper part of each layer being usually of a lighter colour than the lower part, and each separable from that immediately above or below it. But, as will hereafter be explained, this appearance was local and the effect of a secondary cause, and was not produced by the regular annual inundation.

The height of the banks of the river generally diminishes from Assouan to the Delta, and thence in a greater ratio to the mouths of the river, owing to the wider extent over which the mud-charged waters spread below the point of the Nile's bifurcation below Cairo. About the time of the medium rise of the river the banks below Thebes are usually from 20 to 30 feet above the surface of the water, at Cairo from 15 to 25 feet, at Rosetta from 3 to 12 feet.

The annual deposit is variable in thickness in different parts of Upper Egypt and in the Delta from a variety of causes, and that both in the vicinity of the river and at a distance from it. In the vicinity of the river, at particular places, where the stream is retarded by the comparative flatness of the country, the deposition is greater than in other localities. The deposit of one year is in some places stripped off by the flood of the next, and the quantity of earthy matter held in suspension in the water is sometimes augmented by portions of the mud cliff falling into the river. M. Melly, writing from Tahtah on the 3rd of November 1850, says, "Le Nil est déjà

* Rozière, Description de l'Egypte, vol. xx.

descendu de $1\frac{1}{2}$ à 2 pieds, et partout il dégrade les bords à tel point, qu'on voit à chaque moment une série d'avalanches du plus beau terroir noir imaginable:" and on the following day he says, "Nous sommes arrivés à Girgeh, une des villes de la haute Egypte, qui était trois fois plus grande il y a quelques années qu'aujourdhui, mais un courant du Nil qui s'est determiné contre la colline friable sur laquelle elle est bâtie, en enlève des quartiers entiers de tems à autre. Une portion des maisons et une mosquée, dont la moitié est déjà tombées dans le Nil, ressemblent aux gravures du Diable Boiteux, seulement que ces débris ne sont pas habités." The sediment of one year is also carried back into the river the following year from another cause:—"Pendant trois ou quatre mois de l'année, la surface de l'Egypte, dénuée de végétation, sèche et pondreuse, est balayée par des vents violents, qui soulèvent dans les airs la poussière du sol, en laissant précipiter une partie dans le fleuve, qui l'entraine à la mer, et en dispersent une autre partie dans les déserts, ou l'accumulent sur d'autres portions de l'Egypte*." At a distance from the river, especially in those parts which are in the vicinity of valleys or gorges, in the lateral ranges of hills, blown sand from the desert is often mixed with the mud of the river that is spread upon the land.

In all calculations, therefore, as to the secular increase of the deposit, by measurements of its depth, we must take into our consideration whether the pits or the borings have been made in places least liable to these irregularities; whether the solid matter held in suspension may not have been augmented by portions of former deposits washed or falling into the stream; and whether the mud deposited by the river has had no intermixture of blown sand.

The following observation of the traveller Rüppell is a remarkable indication of an accumulation of the Nile sediment in the Faiûm, at a distance of about twenty-five miles from the left bank of the river:—"I had a desire to visit Lake Mœris and its islands, and quitted Medina in a north-east direction, travelling over very fertile plains. In the neighbourhood of a large village called Fedimin, we passed the dried-up bed of a very deep canal, in the side of which I saw, to my great surprise, horizontal beds of the mud of the Nile, having a depth of sixty feet†."

THE RECENT RESEARCHES.

The first step which I had to take in this inquiry was to decide upon the situation in which the proposed vertical shafts should be sunk. As the neighbourhood of Cairo might afford great facilities for prosecuting the work, as the standing obelisk of Heliopolis is one of the most ancient of the existing monuments, and as the time of its erection has been made out on very reliable grounds, I chose that spot.

Having obtained an introduction to A. C. Harris, Esq., of Alexandria, well known by his active and long-continued researches in Egyptian antiquities, I requested him

* De la Constitution physique de l'Egypte, Hist. Nat. ii. 493.

† Letter in Baron de Zach's Correspondance Astronomique, vol. vii. p. 245.

to endeavour to find some one resident in Cairo who might be capable of conducting the contemplated operations, explaining my views to him in the following terms:—

"I am anxious to investigate in a more satisfactory manner than has yet been done, the frequently agitated question, how far the sedimentary deposits of the Nile afford a chronometric scale that will carry us back beyond what may be termed the known zero of authentic historical time. There is every reason to believe, that, reckoning from century to century, the average increments of the deposits are pretty regular, due care being taken to make the observations in a part of Egypt where there is not likely to exist any abnormal state of the solid contents held in suspension in the Nile water, from the breaking down of a part of its banks. But I have not been able to discover that any borings have been made with much care since those by the French in Upper Egypt in 1799, and those recently at the Barrage of the Nile by Mougel Bey. What is wanted is this: to have a pit sunk in a situation where the Nile deposit has accumulated over or close to some of the most ancient works of art known to exist, and the date of the foundation of which is known with tolerable certainty, such as the Obelisk at Heliopolis; the strata in such a pit being regularly marked as to their several thickness and their composition, and specimens of each variety being taken. This being done, to the lowest part of the foundation of the monument, the excavation to be continued as far downwards as any sediment is found having the known characters of the Nile deposit, carefully noting the dimensions of the several layers gone through below the lowest part of the artificial structure, or foundation of the same. Such an examination could not be carried on with trustworthy value except by or under the immediate superintendence of some one capable of directing it, and of ensuring accuracy in all the successive excavations."

Mr. Harris applied to his friend Hekekyan Bey, an Armenian gentleman resident in Cairo, who had been educated and long resident in England, and who, as a Civil Engineer, had occupied some important positions in the service of the Viceroy Mehemet Ali, especially as Chief of the Polytechnic School in Cairo. Hekekyan Bey most readily accepted the proposal, evincing an earnest desire to be employed in a scientific inquiry of this nature. How fortunate I have been in obtaining such valuable cooperation will fully appear in the sequel. But nothing could be done without the previous consent of the then Viceroy Abbas Pacha, the more especially as the spot where I wished the excavation to be made, close to the Obelisk of Heliopolis, is in a garden belonging to the Pacha, into which the site of the renowned city has been converted. Through the active intervention of the Hon. Charles Augustus Murray, at that time Her Majesty's Agent and Consul-General in Egypt, and who, during the remainder of his stay in the country, took a warm interest in the inquiry, and continued to give me his powerful support, the consent of the Viceroy was obtained. His Highness not only acceded to the request, but directed his ministers to place at the disposal of Hekekyan Bey, whom he appointed to conduct the opera-

tions, whatever was necessary to carry them out in the most complete manner, but with truly royal munificence told Mr. MURRAY that the whole expense of them should be defrayed by his Treasury.

When I submitted my proposal to the Council of the Royal Society, I did not contemplate the accomplishment of anything beyond the sinking of a few pits; but I had now the prospect of researches being made on a great scale; how widely they were afterwards extended, by the continued exertions of Mr. MURRAY and of his successor the Hon. FREDERICK BRUCE, and by the unabated liberality of the Viceroy, will appear in the course of this memoir.

It may appear remarkable to many, as it had done to CUVIER, that researches of this nature had not been undertaken before. With the exception of the corps of scientific men appointed by the French Government to accompany the Egyptian expedition under General BUONAPARTE, very few of those who have visited Egypt have turned their attention to geological researches; most travellers have been attracted by the interesting objects of art and the history of the people. In the introduction to his memoir 'Sur la vallée d'Egypte,' M. GIRARD* observes,—"Parmi les nombreux voyageurs qui ont donné des descriptions de l'Egypte, il n'en est aucun qui se soit proposé d'examiner la Vallée où coule le Nil, avec assez de détails pour conclure, de son état present, les changemens successifs qu'elle a subis et ceux qu'elle doit éprouver dans la suite" (p. 185); and at p. 251 he goes on to say, "La question de l'exhaussement du sol de l'Egypte, et de l'accroissement du Delta, avait été traitée, jusque dans ces derniers temps, ou par des voyageurs qui ne faisaient pas de cette question un objet particulier de recherche, ou par des érudits qui prétendaient l'éclaircir en essayant de concilier certains passages d'auteurs anciens contradictoires entre eux, ou du moins que leur obscurité rend susceptibles d'interprétations différentes. On ne pouvait espérer d'obtenir une solution complète de cette question, que lorsque les géologues et ceux qui ont fait une étude particulière de la théorie des cours des fleuves s'en seraient emparés."

But the operations of which I am about to give an account are of a nature and extent that scarcely any individual traveller could undertake; for they have required a large body of men, and some of them practised in the art of surveying; and as they could only be carried on after the waters of the inundation have subsided for some time, and therefore at a season of the year when the heat is excessive, those only inured to the climate could undertake such a work.

I explained my views as to the manner in which I desired that the researches should be carried on in the following directions to HEKEKYAN BEY:—

"Mr. HARRIS has communicated to me your most obliging letter to him, in which you so warmly enter into the subject of my correspondence with him, viz. the institution of experiments to measure the depth of the alluvial deposits of the Nile, with

* Mémoires de l'Académie Royale des Sciences de l'Institut de France, année 1817, p. 185.

reference to the great question of the duration of its secular increase. I rejoice to think that I am to have so able a coadjutor on the spot, for in the prosecution of this inquiry you may solve some of the most interesting questions in the history of ancient Egypt. Your suggestions as to the spots where the shafts should be sunk around the Obelisk of Heliopolis are excellent.

"In carrying the plans into execution, it is important that the following particulars should be attended to:—

"1. To make a ground plan of the space around the obelisk within which the shafts are to be sunk, marking the exact spot of each shaft and its distance from the obelisk.

"2. In digging the shaft A, to mark the depth from the highest point upon or near to the obelisk which the alluvial deposit now reaches to the base of the masonry on which the obelisk stands.

"3. If the above masonry rests on rubbish or on Nile mud; if the former, the nature of the rubbish and its thickness.

"4. If the rubbish rests on Nile mud.

"5. The sinking of the shaft to continue so long as it passes through characteristic Nile mud, marking the depth of the mud.

"6. If the mud be completely penetrated through, the nature of the ground on which the lowest layer of mud rests.

"7. In all the shafts sunk, to note every change in the nature of the soils passed through, and to preserve a specimen of each variety of soil, carefully marking the specimen with a number referring to a catalogue descriptive of the sinking.

"8. To examine carefully whether there are any shells or other organic bodies in the soils passed through; and if so, to preserve them, marking each specimen in the way mentioned in No. 7.

"9. If any fragments of human art be found in the soils passed through; and, unless they be brick or other rude material, to preserve them, marking each specimen in the way mentioned in No. 7.

"10. To note the thickness of the layers of Nile deposit, and the number of them in a given space, say a foot."

On the 3rd of June 1851, Hekekyan Bey wrote to me as follows:—"His Highness the Viceroy has been pleased to grant every aid and means required for the execution of the works of research at Heliopolis, consequently I trust that your plans will be carried out to your complete satisfaction. Arrangements have been made to commence working at Heliopolis on the 10th of this month. During the operations I shall most scrupulously adhere to the general directions with which you have favoured me."

The Excavations at Heliopolis.

At a distance of about five and a half miles N.N.E. of Cairo, and less than four miles, at the time of low water, from the right bank of the Nile, the traveller discovers the solitary Obelisk of Heliopolis, all that remains above ground of that once renowned city of the Pharaohs, the On of Scripture. This obelisk, the oldest known, was erected by Sesurtesen (Sesortosis I. of Manetho) of the Old Monarchy, and the twelfth Dynasty, about 2300 years before Christ, according to LEPSIUS, and has thus stood at least 4000 years, which, according to the *marginal* chronology printed in the latest editions of our Bibles, is about 300 years before the death of Noah*.

The obelisk is a single block, measuring from the pedestal on which it rests, 67 feet 6 inches, its faces being 6 feet 6 inches at the base, and tapering to 3 feet 10 inches at the lowest line of the pyramidal summit. It is of red granite, such as is found in the district of Assouan, and was doubtless transported from the quarries in that locality.

The walls which surrounded the city are still to be traced by long mounds of earth, covering the unbaked bricks of which they were constructed, in some places from 60 to 65 feet in width, and from 13 to 16 feet in height, enclosing an area of about 1540 by 1100 yards. These mounds are now much more than sufficiently high to keep out the greatest inundation; formerly the water entered by gaps and converted the interior area into a marsh; but in the time of MEHEMET ALI embankments were raised to keep out the inundation water and render the ground cultivable. The land immediately eastward of the obelisk rises abruptly; it is composed of coarse sand and marl, and is out of the reach of the inundation. It appears probable that the site originally chosen for the temple and city of Heliopolis was a portion of the desert line somewhat raised above the level of the rest of the skirt of the desert, and advancing into the low grounds then inundated by the Nile.

On the 8th of June 1851, forty labourers, under the direction of OMAR EFFENDI Adjutant of Artillery, were on the ground. The next day was devoted to arrangements, the men being shown where and how the works were to be commenced, and explanations given, that they might have some idea of the nature and object of the operations. A party of young engineers from the Polytechnic School in

* "Eben so wenig findet sich bei den Ægyptern irgend eine Andeutung einer grossen Fluth. Dass im ganzen Verlauf ihrer Geschichte keine grosse Naturveränderung, keine unheilvolle Katastrophe stattgefunden habe, wurde dem Herodot ausdrücklich von den Priestern bezeugt, und es möchte nach seinen Worten fast zu vermuthen sein, dass er diese bestimmte Versicherung erst auf Nachfragen erhielt, welche gerade durch die ihm wohl bekannten Fluthsagen anderer Völker bei ihm veranlast waren. Seit Menes (3892 B.C.), hätten ihm die Priester gesagt, habe sich nichts auf Ægypten bezugliches geändert, weder in Bezug auf ihr land, noch auf ihren Fluss, noch in Bezug auf Krankheiten, noch auf Sterbefälle. Herodot. ii. 142."—LEPSIUS, Chronologie der Ægypter, Einleitung, s. 24.

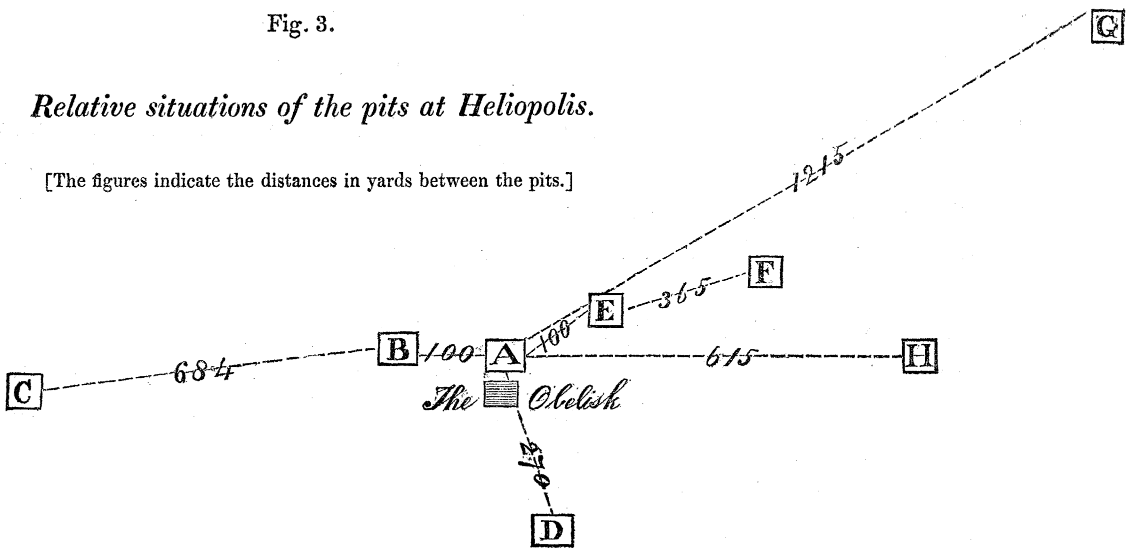
Cairo was afterwards added, with the necessary instruments, to make plans and sections and to take the levels of the ground. Twenty Bedouin labourers were also engaged.

Eight pits or excavations were sunk around the obelisk at different distances, in the situations indicated in the annexed ground plan, and they were carried down to the lowest level of the waters of infiltration in the Heliopolis district on the 16th of July.

Fig. 3.

Relative situations of the pits at Heliopolis.

[The figures indicate the distances in yards between the pits.]



Before beginning to describe the several excavations, it will make the descriptions of them more intelligible and will save repetitions, if I give an account of the nature of the soils sunk through.

As it was to be expected that, on the same level, and within a space of moderate extent, there would be an identity of composition, I requested Hekekyan Bey to send me specimens of all the varieties of soil he met with in sinking the pits, he himself keeping corresponding specimens; thus establishing a standard to refer to in his reports, and saving the necessity of sending specimens of identical alluvia. My request however was not made until he was carrying on similar researches in the district of Memphis, and they were selected from his excavations there; but they have equally served as a standard of comparison for the soils sunk through at Heliopolis, samples of which were in my possession when I made the request.

All the Nile mud, properly so called, has at one time or other been suspended in its water. I was therefore desirous that an experiment should be made to ascertain the quantity of solid matter held in suspension in the water, at a given place near Cairo. Having communicated my wish to Mr. Murray, he prevailed upon Dr. Abbott, a physician long resident at Cairo, to undertake the inquiry. I then described the process and apparatus by which I had in the year 1832 ascertained the amount

of solid matter held in suspension in the water of the Rhine, and requested that a similar process should be followed*. Dr. ABBOTT's account of his experiment, contained in a letter to me dated Cairo the 12th of December 1850, is as follows:—"I began your experiment on the 1st of October, and on that day took an imperial gallon of water from the Nile at the depth of 20 feet, and at that part of the river opposite the Transit Wharf at Boulac. The current is there very strong, and the water is not likely to have any of the dirt or filth that might possibly be mixed with it lower down, where a large number of boats are collected. I took one gallon of water daily for ten days, which I put into an earthen filter, and left covered, until it became perfectly dry; and then put it into a paper and kept it until a week ago, when I weighed it and found the quantity to be 18½ drachms apothecaries weight (1110 grains). I am now endeavouring to dry it in a cake, or rather to bake it in the form of a small brick to send to you."

I weighed the little brick sent to me accurately on the 11th of May 1851, and found it to be 1106 grains, so that the solid matter held in suspension is 110·6 grains in an imperial gallon. An analysis of this solid matter was made at the Royal College of Chemistry in London, by Mr. BRAZIER, under the superintendence of Dr. HOFMANN†, and yielded the following results:—

Silica	53·04
Sesquioxide of iron	18·43
Sesquioxide of alumina	8·76
Carbonate of lime	4·19
Sulphate of lime	0·75
Lime	2·25
Magnesia	0·66
Potassa	0·69
Soda	2·16
Chloride of sodium	0·04
Organic matter	9·03
	100·00

This hardened mass, when moistened, kneaded into a clay.

In future references to this specimen I distinguish it by the letter A.

B. *A specimen of Nile sediment from the lower part of the Delta, sent to me by Mr.* MURRAY.—It was collected at Damanhour, about six miles and a half from the left bank of the Rosetta branch, from a branch canal which connects the Nile with the Mahmudieh Canal near Bastié, and was a part of the sediment deposited by the inundation of 1849. This deposit is carefully collected on account of its ferti-

* Edinburgh New Philosophical Journal, January 1835.

† That the accuracy of the analyses might be relied on, I requested and obtained the aid of my distinguished friend Dr. HOFMANN, who kindly undertook the superintendence of this and of the other analyses hereafter mentioned.

lizing properties, and brought to improve the gardens near Alexandria. It is a fine-grained blackish-grey, loosely coherent earth. It was analysed by Mr. JOHNSON at the Royal College of Chemistry, under the superintendence of Dr. HOFMANN, and yielded the following results:—

Silica	56·86
Sesquioxide of iron	13·19
Alumina	12·11
Carbonate of lime	3·12
Sulphate of lime	0·38
Lime	3·53
Magnesia	2·73
Potassa	0·90
Soda	0·89
Chloride of potassium	0·57
Organic matter	5·53
Loss	0·19
	100·00

On the application of Mr. MURRAY, MOUGEL BEY, the French Engineer of the Barrage of the Nile, was so obliging as to send me ten specimens of the soils penetrated at different depths in sinking the foundations. These were analysed at the Royal College of Chemistry by Mr. BRAZIER, and gave the following results:—

C.—A greenish grey, smooth, fine-grained earth, which when moistened kneads into a somewhat gritty clay. The exact locality was not given, but MOUGEL BEY describes it thus: "Dans les couches d'argile on trouve des nids de limon ferrugineux que les Fellahs emploient comme amendement sur les terres."

Silica	49·77
Sesquioxide of iron	22·25
Sesquioxide of alumina	5·49
Alumina	7·38
Carbonate of lime	3·37
Lime	1·53
Magnesia	0·14
Potassa	0·77
Soda	0·37
Sulphuric acid	0·15
Phosphoric acid	traces
Organic matter	8·78
	100·00

D.—A blackish brown earth, very much resembling A. except in colour. Like it, when moistened, it kneads into a clay. From the apex of the Delta, on the right bank of the Damietta branch, and from a depth of nearly 20 feet from the surface.

Silica	54·99
Sesquioxide of iron	21·04
Sesquioxide of alumina	11·14
Carbonate of lime	4·20
Lime	3·08
Magnesia	0·17
Potassa	0·69
Soda	0·46
Sulphuric acid	0·12
Phosphoric acid	trace
Chlorine	trace
Organic matter	4·11
	100·00

E.—A blackish brown earth, undistinguishable in external characters from D. From the left bank of the Rosetta branch, and behind the dyke, at a depth of about 20 feet from the surface.

Silica	55·66
Sesquioxide of iron	15·94
Sesquioxide of alumina	4·60
Alumina	5·80
Carbonate of lime	5·26
Lime	3·42
Magnesia	1·03
Potassa	0·74
Soda	0·55
Sulphuric acid	0·33
Phosphoric acid	traces
Chlorine	traces
Organic matter	6·67
	100·00

F.—A blackish brown earth, similar to D. and E. in external characters, but indurated: when reduced to powder, not distinguishable from them, but when moistened it kneads into a more plastic clay than they do. From the same locality as D, but at a depth of only 5 feet 3 inches.

Silica	52·76
Sesquioxide of iron	24·94
Sesquioxide of alumina	13·84
Carbonate of lime	2·95
Sulphate of lime	0·83
Lime	0·94
Magnesia	trace
Alkalies	trace
Chlorine	trace
Organic matter	3·74
	100·00

G.—Very similar to F. in external characters, but the colour inclining more to red. From the same locality as E, but at a depth of only 5 feet 3 inches from the surface.

Silica	57·96
Sesquioxide of iron	19·04
Alumina	11·85
Carbonate of lime	6·65
Lime	0·56
Magnesia	1·37
Alkalies	trace
Chlorine	trace
Organic matter	2·57
	100·00

H.—Almost identical in external characters with E. in all respects. From the same locality as D. and F, but at a depth of 9 feet 10 inches from the surface.

Silica	55·64
Sesquioxide of iron	26·89
Sesquioxide of alumina	7·52
Alumina	4·76
Carbonate of lime	trace
Organic matter	5·19
	100·00

Composition of the eight specimens of Nile mud, taken from different localities and at different depths.

	A.	B.	C.	D.	E.	F.	G.	H.	Average.
Silica	53·04	56·86	49·77	54·99	55·66	52·76	57·96	55·64	54·585
Sesquioxide of iron	18·43	13·19	22·25	21·04	15·94	24·94	19·04	26·89	20·215
Sesquioxide of alumina	8·76	......	5·49	11·14	4·60	13·84	......	7·52	6·418
Alumina	......	12·11	7·38	......	5·80	......	11·85	4·76	5·237
Carbonate of lime	4·19	3·12	3·37	4·20	5·26	2·95	6·65	trace	3·717
Sulphate of lime	0·75	0·38	......	......	......	0·83	......	......	0·245
Lime	2·25	3·53	1·53	3·08	3·42	0·94	0·56	......	1·912
Magnesia	0·66	2·73	0·14	0·17	1·03	trace	1·37	......	0·762
Potassa	0·69	0·90	0·77	0·69	0·74	trace	trace	......	0·473
Soda	2·16	0·89	0·37	0·46	0·55	trace	trace	......	0·553
Chloride of potassium	......	0·57	......	......	......	......	......	......	......
Chloride of sodium	0·04	......	......	......	......	......	......	......	......
Chlorine	......	......	......	trace	trace	trace	trace	......	......
Sulphuric acid	......	......	0·15	0·12	0·33	......	......	......	......
Phosphoric acid	......	......	trace	trace	trace	......	......	......	......
Organic matter	9·03	5·53	8·78	4·11	6·67	3·74	2·57	5·19	5·701
Loss	......	0·19	......	......	......	......	......	......	......
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	

I.—Grey sand, composed of rounded and angular transparent quartz, some opake, and minute white, brown, and black particles. I could not discover with a strong

magnifier any quartz crystals with their faces entire, nor any scales of mica. As it effervesces briskly with acid, the white particles are probably carbonate of lime. From the apex of the Delta, on the left bank of the Rosetta branch, behind the dyke, at a depth of 16 feet 4 inches from the surface.

Silica	71·76
Alumina	10·40
Sesquioxide of iron	7·81
Carbonate of lime	6·77
Magnesia	0·76
Organic matter	2·50
	100·00

K.—Sand very similar to I, but more exclusively quartzose and with a few scales of mica, with some hard concretions of sand. From the right bank of the Damietta branch, at a depth of 31 feet from the surface.

Silica	85·31
Sesquioxide of iron	5·98
Sesquioxide of alumina	1·72
Alumina	1·04
Carbonate of lime	3·64
Organic matter	2·31
	100·00

L.—Brown quartzose sand, very similar to K. Taken from the surface, near the river, at the time of low water, on the left bank of the Rosetta branch.

Silica	83·21
Sesquioxide of iron	6·01
Sesquioxide of alumina	4·09
Carbonate of lime	4·72
Organic matter	1·97
	100·00

M.—A light brown sand, consisting almost exclusively of transparent quartz with a few minute brown and green particles interspersed, effervescing slightly with acid. From the same locality as L, but from a depth of 67 feet 3 inches from the surface.

Silica	96·93
Sesquioxide of iron	2·05
Sesquioxide of alumina	1·02
Lime	trace
	100·00

It will be seen that the two specimens of the present superficial Nile mud, B and C, taken from localities widely apart, although consisting of nearly the same ingredients, differ considerably in the proportions. But in a deposit of this mechanical nature, it is probable that no two specimens, although taken from localities near to

each other, would yield the same proportions in a chemical analysis. It will be observed how very similar they are in composition to the solid matter suspended in the water of the Nile, collected by Dr. ABBOTT, Specimen A.

The samples of the alluvial soils penetrated in the excavations, forwarded to me by HEKEKYAN BEY, are divisible into two classes, each offering several varieties, viz. into blackish brown argillaceous sandy earths, and into sands. As all of them closely resemble in external characters the specimens analysed, as above described (A. to M.), it was not deemed necessary for the object of this inquiry to have *the samples* analysed also; but that it would be sufficient to refer them to the analysed standard specimens. They may be thus described:—

No.	Nature of the soil.	Standard specimen it closely resembles in external characters.
	EARTHS.	
I.	A blackish brown, fine-grained indurated earth, not distinguishable in external characters from	F.
II.	A blackish brown, fine-grained indurated earth, not distinguishable from No. I., except in being a shade lighter in colour........	F.
III.	A blackish brown, fine-grained indurated earth, identical with No. I., except in having interspersed some white calcareous concretions...	F.
IV.	A blackish brown, fine-grained indurated earth, containing the same white concretions as No. III., and some small rounded fragments of burnt brick. It closely resembles No. I., but is more argillaceous	F.
V.	A blackish brown earth, the indurated parts of which, when reduced to powder, are not to be distinguished from B. It contains fragments of brick........	B.
VI. and VII.	A brown, very friable sandy earth, with minute scales of mica, closely resembling L.	L.
VIII. and IX.	A brown, fine-grained indurated earth, not to be distinguished from No. II........	F.
	SANDS.	
X.	Quartzose sand, containing rounded quartz pebbles, and fragments of burnt brick, desert sand, closely resembling M.	M.
XI.	Quartzose sand, with a few scales of mica; desert sand. Identical with K.	K.
XII., XIII., XIV.	A brownish white quartzose sand, with some aggregated portions, and fragments of bone and burnt brick. Similar to L.	L.
XV.	Fine quartzose sand, nearly identical with	K.
XVI.	A brown argillaceous earth, mixed with quartzose sand, partially aggregated, and containing white calcareous concretions	H. and B.
XVII.	Yellowish white, pulverulent, argillo-calcareous sandy earth, kneading into clay when moistened, partially aggregated. It is called in Egypt "Fine Potter's Earth."	

Besides the above samples, I. to XVII., HEKEKYAN BEY distinguishes in his sections of the pits layers of soils which are mixtures of the above varieties; thus we have

No.	Nature of the soil.
XVIII.	A mixture of black mud with clay, as if they were kneaded together.
XIX.	A mixture of compact black mud, clay and river-sand in nearly equal quantities.
XX.	Nearly equal proportions of compact black mud, river-sand and fine rubbish.
XXI.	River-sand mixed with a little black mud.

It will be seen that in all the excavations the downward progress was interrupted by filtration water. This is mainly derived from the Nile, but occasionally from side torrents after rain. As the river rises, the level of the water absorbed by the soil on its banks does not keep pace with the rise, for the water takes time to spread laterally, according as the soil is more or less pervious; and should its descent be impeded by a compact layer, it will continue to spread until it is exhausted at a considerable distance from the river. When the Nile falls, that portion of the filtration water which has not penetrated the soil to a depth below the river's ebb level, returns into the channel; but the amount returned will also depend upon the more or less pervious nature of the soil; and when retained by a compact layer, it will remain for some time at a higher level than the falling surface of the Nile.

EXCAVATION A.

Ten men were set to work at this spot. A trench was commenced from a point opposite to and 40 feet distant from the north face of the obelisk, and carried southwards, descending by steps, so as to form an inclined plane downwards. In two days the upper surface of a red sandstone block was reached, being the pedestal upon which the granite obelisk immediately rests. The upper surface of this block was 5 feet 6 inches below the surface of the ground immediately round the obelisk.

A trench was opened opposite to the southern face of the obelisk, 35 feet distant from it, and when carried forward laid bare the pedestal to a depth of $4\frac{1}{2}$ feet from its upper surface. The filtration water having been reached, it was baled out, and it was discovered that the pedestal rests immediately on two layers composed of several blocks of limestone, and under the lower of these white sand was found. The pedestal is 6 feet $10\frac{1}{2}$ inches in height; the first layer of limestone on which it rests is 1 foot 4 inches, the lower layer 1 foot 3 inches in thickness. The limestone is the nummulite limestone of the country; the sandstone of the pedestal is identical with that of the neighbouring hill, Gebel Achmar, that is, the upper sandstone in an indurated state.

An iron bar, 16 feet long and $1\frac{1}{2}$ inch in diameter, was worked perpendicularly by

eight men into the sand close to the platform, to a depth of 3 feet $2\frac{1}{2}$ inches under the inferior line of the lower layer of limestone, without meeting with any obstacle from any solid matter, and when passed in a slanting direction 30 inches within the edge of the limestone, still no impediment was met with. Sixteen men were employed to bale out water and sand until a diver was enabled to extract some sand from under the limestone platform, which was fine-grained, white, and very clean.

The total depth of the soils sunk through in a vertical direction was 14 feet 6 inches to the level of the filtration water, which, together with the 8 feet 2 inches of sand penetrated beneath the filtration water, makes the total depth 22 feet 8 inches. The soils exhibit the following varieties, and it will be observed that the Nile mud is here not deeper than 9 feet 11 inches.

Specimen.	Feet.	Inches.	
		9	Disturbed ground mixed with rubbish.
1.	4	11	Undisturbed Nile sediment, with fragments of limestone about the size of a bean, rounded; also fragments of pottery. Slender vegetable fibres are scattered through the mass. It is an indurated earth, similar to the analysed specimen F, and to the sample No. I., but containing a small admixture of quartzose sand, and when moistened it kneads into a plastic clay.
2.	4	10	Termed by Hekekyan Bey "rubbish soil." It is a mixture of the blackish brown earth, sample No. I., with many calcareous particles and fragments of limestone, and some fragments of pottery. Near the bottom of the layer was found a band of 7 inches of sand.
3.	4	...	Coarse grey sand, with coral-shaped concretions of the sand, extending to the filtration water. In this layer was found a portion of an eight-sided column of dark green basalt. Near the surface of the water, the sand contained the right upper molar of a ruminant, of the size of a sheep, and the first molar, left side, of the upper jaw of an ass (*Equus Asinus*)*.
	14	6	Level of filtration water.
4.	1	6	Sand nearly identical with No. 3.
	6	8	Sand of the same kind from underneath the lowest limestone flag, containing coral-shaped concretions of sand.
	22	8	

Excavation B.—100 *yards west of* A.

Ten men were set to make this excavation, across the ancient great western avenue leading to the obelisk†. The total thickness of the soils sunk through, from the

* All the fossil bones found in the excavations were submitted by me to Professor Owen, and have been described by him.

† In the various excavations which have been made in the prosecution o this inquiry, many objects of art of historical interest have been discovered; but as these do not come within the province of the Royal Society, I propose to give an account of them in a memoir to be laid before another learned body.

surface of the ground to the level of the filtration water, was 12 feet 3 inches, and a vertical section exhibits the following varieties:—

Speci-men.	Feet.	Inches.	
1.	6	7	The surface layer of Nile mud. A blackish brown, fine-grained, indurated earth, not distinguishable from the sample No. I., and the analysed standard specimen F; neither is it distinguishable from layer 1. in Excavation A.
2.	1	10	A grey, sandy, pumiceous-looking earth, effervescing briskly with acid, and when moistened, kneading into a plastic clay. Except in being darker in colour, it closely resembles sample No. XVII. in all its characters.
3.	3	10	A dark brownish black sandy earth, closely resembling the analysed standard specimen B, which is a superficial Nile mud. Both effervesce with acid.
	12	3	Level of the filtration water.
4.	...	...	This specimen was obtained from under the surface of the filtration water, at a depth of about a foot. It is identical with the layer above, No. 3.

Here we have 13 feet 3 inches of Nile mud.

Excavation C.—684 *yards distant from* B, *and* 784 *yards due west of the obelisk.*

In this locality ten men were set to work, while others were employed at the excavations A, B and D. A trench was cut from north to south, across the line of the supposed avenue of Sphinxes, and in the progress of the excavation they came upon numerous blocks of stone, the remains of a pavement, and even fragments of a colossal Sphinx, which interrupted the regular vertical sinking. The excavations were carried round these obstructions, on the north of the trench to the depth of 12 feet 9 inches, on the south to the depth of 13 feet 10 inches from the surface to the level of the filtration water. Vertical sections of the soils sunk through exhibit the following varieties:—

Specimen.	North end. Feet.	Inches.	
1.	5	11	Surface layer. A mixture of Nile mud, a blackish brown earthy sediment, with angular and rounded fragments of limestone*, bricks and pottery, and angular fragments of the sandstone of Gebel Achmar. In the inferior part of the layer were found fragments of a marrow-bone of a herbivorous animal. It is undistinguishable from layer No. 1. of the south end.
2.	2	0	A light brown, sandy, calcareous earth, very similar in appearance and characters to layer No. 2. in Excavation B, except in being somewhat darker in colour. It contains angular fragments of limestone. It is identical with layer No. 2. of the south end.
3.	1	5	A light brown, sandy earth, similar to the preceding layer, but more like layer No. 2. in Excavation B. It contains fragments of bricks and pottery. It is identical with the layer No. 3. of the south end.
4.	3	5	A light brown, sandy earth, very similar to layer No. 3. in Excavation B, except in being lighter in colour. It contains fragments of coarse pottery. It is identical with layers No. 3. and 6. of the south end.
	12	9	Level of the filtration water.
5.	1	6	Identical with the preceding, and containing fragments of chert, limestone and pottery.

Specimen.	South end. Feet.	Inches.	
1.	3	$7\frac{1}{2}$	Surface layer. The same in all respects as layer No. 1. of north end. There was found in it a broken shell of *Murex trunculus*, a living Mediterranean species; remarkable in being found so far from the sea, but it may have been carried by a bird. The freshwater shell *Paludina impura* or *tentaculata* was also found †.
2.	3	0	The same as No. 2. in the north end. Containing also the same *Paludina* as in the layer above, but altered in the substance of the shell by having been long buried in the ground.
3.	0	7	Very similar to No. 2, and identical with Nos. 3. and 4. of the north end, except in being more sandy.
4.	0	4	Identical with No. 2. of this south end, with many fragments of limestone, bricks and pottery.
5.	0	9	Undistinguishable from the preceding, except fewer fragments. In this layer was found a portion of the pectoral fin of a fish.
6.	0	$7\frac{1}{2}$	Undistinguishable from Nos. 4. and 5. of this south end, except in being more sandy.
7.	0	6	Quartzose sand, with small concretions of Nile mud, and rounded fragments of opake quartz and portions of brick.
8.	1	8	Identical in all respects with layer No. 3. of this south end, and with layer No. 5. of north end.
9.	2	7	Identical with the preceding and with layer No. 5. of the north end. Contains fragments of pottery.
	13	10	Level of the filtration water.
10.	1	6	Identical with the above layers 8. and 9, and with No. 5. of the north end.

Here we have 14 feet 3 inches of Nile mud in the north part of the trench, and 15 feet 4 inches in the south end, with an interposed layer of sand of 6 inches.

* All the limestone fragments are the nummulite limestone of the neighbouring hills.

† On examining this shell, Sir C. LYELL observed, that it is rather a large variety and differs from the English ones in a slight degree, coming most nearly to the variety of the same species found in the Norwich Crag; that this is interesting, as the *Cyrena consobrina*, a species now recent in Egypt, is found fossil in the Norwich Crag.

EXCAVATION D.—270 *yards south by east of the obelisk.*

Ten men were set to work at this spot, to deepen an excavation which was made some time before, when a gateway of the time of TUTHMOSIS III. was discovered. A vertical section of the soils passed through exhibits the following varieties:—

Specimen.	Feet.	Inches.	
1.	5	6	The surface layer. It is Nile mud, very closely resembling the sample No. V., and the standard specimen B, as well as layer No. 2. of Excavation C, north end, and layer No. 5. of Excavation C, south end. It is the substance of the crude bricks used in building.
2.	6	11	Similar to the preceding, but more sandy. It contains fragments of brick and pottery. It closely resembles layer No. 3. in Excavation C, south end. Near the surface of this layer were found, the lower end of the right humerus of a ruminant of the size of a sheep, part of the upper jaw of a dog, and the lower jaw of a dog with some loose teeth and the fang of a dog's tooth.
3.	2	10	Quartzose sand, very similar to layer No. 7. in the Excavation C, south end.
	15	3	Level of the filtration water.
4.	...	...	The same quartzose sand as No. 3.

EXCAVATION E.—100 *yards north-east of the obelisk.*

This pit was sunk in a mound. A vertical section of the soils sunk through exhibits the following varieties:—

Specimen.	Feet.	Inches.	
1.	3	2	A brown sandy earth with fragments of limestone. It is identical with the layer No. 2. in Excavation D.
2.	9	4	A brown sandy earth, not distinguishable from the layer No. 1. in Excavation D.
3.	1	7½	Quartzose sand, scarcely distinguishable from the layer No. 7. in the Excavation C, south end.
4.	3	7	A brown sandy earth, scarcely distinguishable from the layer No. 1. of Excavation D.
	17	8½	Level of the filtration water.
5.	...	...	Identical with that immediately above. It was taken from the depth of a foot under the surface of the water.

EXCAVATION F.—365 *yards from Excavation* E, *and about* 383 *yards north-east of the obelisk.*

This excavation was made near an opening in a chain of mounds running N. and S., and parallel to that in which the Excavation E. was made. The opening answers to the entrance of an avenue leading towards the obelisk (the temple) from the east. The space between this chain of mounds and the present line of the desert is called

by the Arabs the Bahr-il-Moussa, or River of Moses. A vertical section of the soils sunk through exhibits the following varieties:—

Specimen.	Feet.	Inches.	
1.	3	6	Surface layer. A blackish brown earth, scarcely distinguishable from the sample No. III.
2.	3	9½	A grey sandy earth, very similar to layer No. 2. in Excavation B, and containing fragments of limestone and brick. In this layer was found a milk tooth (lower molar) of an ox, which had been worn down and shed.
3.	...	10	A brown sandy earth, identical with layer No. 2. in Excavation E.
4.	2	2½	Quartzose sand; the quartz nearly transparent, with rolled fragments of opake quartz and chert.
	10	4	Level of the filtration water.

Excavation G.—1215 *yards north-east of the obelisk.*

This excavation was made in the celebrated melon grounds of Heliopolis, which lie on the Bahr-il-Moussa. A vertical section of the soils sunk through exhibits the following varieties:—

1.	2	6	A brown sandy earth, very similar to layer No. 4. in the Excavation E, and the layer No. 3. in the Excavation F, and containing fragments of limestone.
2.	4	2	A brown sandy earth, very similar to layer No. 2. in the Excavation E, with numerous angular fragments of brick and pottery. The upper molar of an ox was found in this layer.
3.	8	4	Quartzose sand, undistinguishable from layer No. 4. in Excavation F.
	15	...	Level of the filtration water.
4.	...	...	The quartzose sand continued below the water.

Excavation H.—615 *yards east of the obelisk.*

This excavation was made in a line between the obelisk and a line of mounds which probably led to the necropolis of the city, which occupies a wide space of ground on the elevated skirts of the desert, due east of the obelisk. A vertical section of the soils sunk through exhibits the following varieties:—

1.	2	10	Surface layer. A blackish brown earth, similar to layer No. 1. in Excavation F, with fragments of brick.
2.	3	8	Chiefly quartzose sand, with numerous rounded fragments of quartz and chert, and a partial mixture of the brown earth of the Nile sediment.
3.	8	...	Quartzose sand, identical with layer No. 4. in Excavation F, and with layer No. 3. in Excavation G.
	14	6	Level of the filtration water.
4.	...	...	The same sand continued below the water.

Synopsis of the Soils sunk through in the nine excavations at Heliopolis.

By an examination of the preceding tables and the diagram, Plate IV., it will be seen that the soils consist of two principal kinds :—

I. Earths (1, 2, 3), more or less sandy and calcareous, varying in colour from a dark blackish brown to a light grey, but evidently so nearly allied, passing by such insensible shades into each other, and having, with slight variations, so great a resemblance to the modern Nile sediment, that they may all be classed as belonging to what is commonly called Nile mud, the earthy matter deposited by the river during the inundations; and

II. Sands (4, 5, 6, 7), partly mixed with indurated portions of Nile mud, but chiefly a pure quartzose sand, similar to that of the adjoining desert.

I have distinguished the chief varieties of each kind by different shadings in the accompanying Plate; whereby it will be more readily seen, that in the same horizontal plane, even in this limited space of half a square mile, there is a very considerable difference in the nature of the soil. Although it might, *à priori*, have been expected that fine earthy particles gradually subsiding from tranquil water, year after year, would form a series of thin layers, in none of the excavations was there an instance of the lamination of the sediment. To this remarkable fact, observed in all the excavations, both here and on the site of Memphis, I shall have occasion to refer in a subsequent part of this memoir.

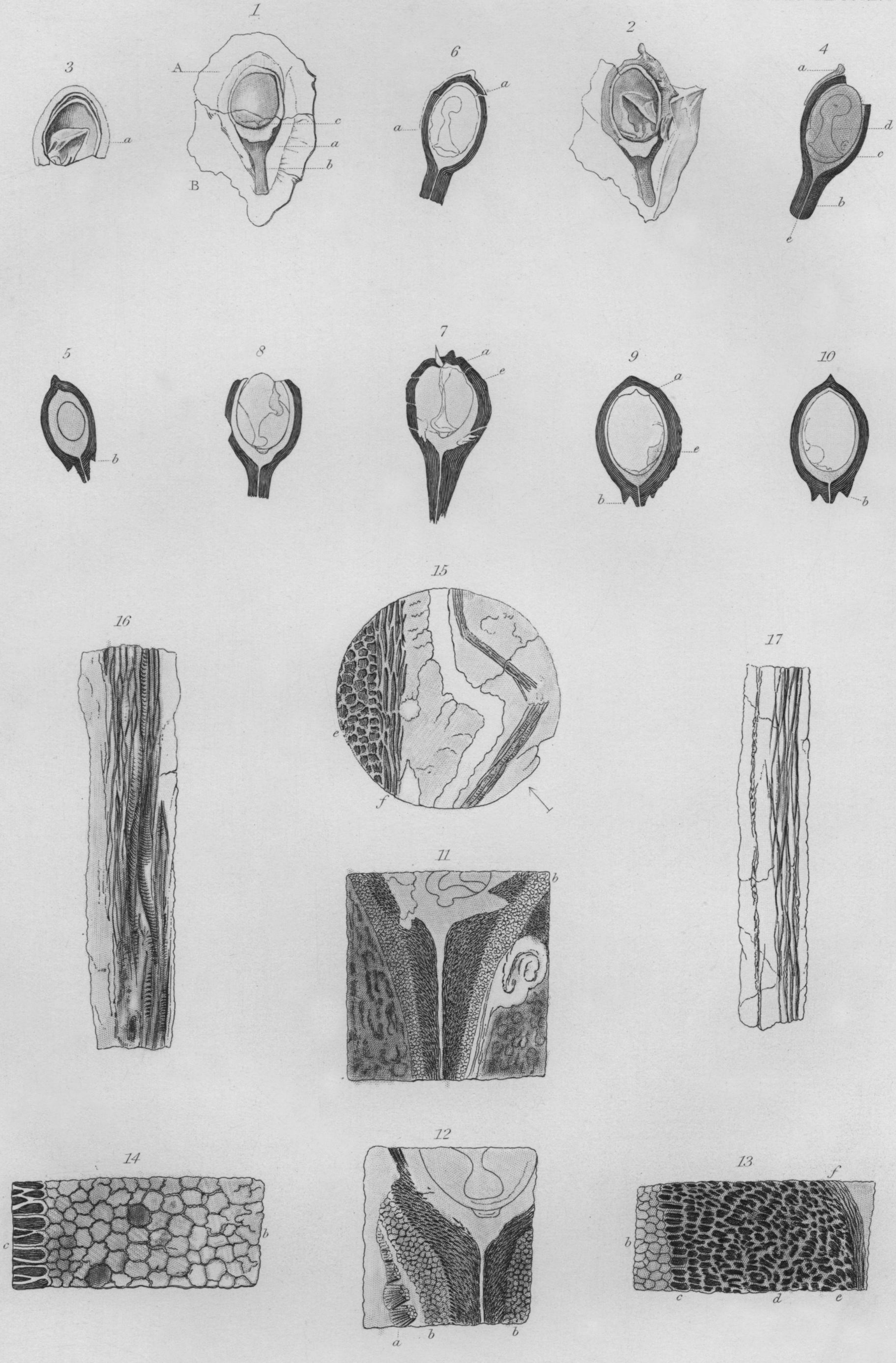
When we consider the small amount of sediment left annually by the inundation in any one place, it is very difficult to conceive how there should be in any one spot so great a thickness of one kind of sediment without any lamination or other sign of successive deposition. For example, in the Excavation E. there is scarcely any perceptible difference in the nature of the soil to a depth of $12\frac{1}{2}$ feet, a thickness which, if accumulated by annual deposits, would be the work of a vastly long period*. But this great amount of thickness of one kind of soil becomes still more remarkable when we find other varieties at the same level in the immediate vicinity, as may be seen in the sections of these excavations. It is evident that other causes than the tranquil operation of annual inundations must have been at work in the formation of this portion of the alluvial land.

The crystalline quartzose sand, it will be seen, was found to the greatest amount in the pits nearest to the desert; and as it is not at all probable that matter so coarse would be suspended in the inundation water, especially in this locality, the layers of sand were most likely blown across the valley from the desert.

But further general remarks, and all inferences as to the secular increase of the alluvial deposits, the main object of this inquiry, I must defer, until I shall have had an opportunity of laying before the Society an account of the far more extensive researches that were carried on in the year 1852 in the district of Memphis, and

* Were we to adopt the estimate of secular increase given by M. Girard, viz. 5 inches in a century, it would amount to 3000 years.

during the last year in a series of seventy-two pits sunk across the valley, in the parallel of Heliopolis, from the Libyan to the Arabian chain of hills. For this great extension of the inquiry I am indebted to the unabated liberality of the Viceroy; to the continued warm interest taken in it by Mr. MURRAY, so long as he remained in the country, followed up as it has been, with equal zeal, by our present Consul-General in Egypt, the Honourable FREDERICK BRUCE; and to the untiring energy of my very able coadjutor, HEKEKYAN BEY.



J. D. Hooker del.

J. Basire, sc.